Radial and Axial Variability of the Proportion of Sapwood and Heartwood in Stems of European Larch (*Larix decidua* Mill.)

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Abstract

In this study an attempt was made to define a diversity in the radial and axial share of sapwood and heartwood in stems of European larch *(Larix decidua Mill.)* grown under different forest site conditions.

The larch trees, which had grown in more fertile habitat as a fresh mixed forest site, was characterized by a bigger share of heartwood, and *ipso facto* a smaller share of sapwood than trees, which had grown in the conditions of coniferous fresh mixed forest site.

Trees from the age class IV (from 61 years old to 80 years old) distinguished themselves by lower share of sapwood than the larch trees which represented V age class (from 81 years old to 100 years old). This relationship was observed in both investigated forest site types.

It was observed radial and axial irregularity of the share of both types of wood in stems the larch from investigated forest type sites and in age classes in connection with tree position in tree stand.

On the share of sapwood and heartwood in tree stem and the velocity of heartwood making process probably can have influence the size and efficiency of transpiration, tree position in stand, as well as forest site conditions in which trees are grown.

Distinct influence of physiologically active tree crown on the sapwood zone in tree stems confirmed by calculation of the coefficient of correlation “r” characterized the relationship between the width of sapwood zone, and the volume and the area of tree crown projection.

Key words: European larch (*Larix decidua*), sapwood, heartwood, fresh coniferous mixed forest site (BMśw), fresh forest mixed site (LMśw)

Introduction

In the year 2005, fresh coniferous mixed forest sites and fresh forest mixed sites occupied all together 41.3% of the forest area in Poland (Raport roczny 2005, strona internetowa lasów państwowych 2007). In these conditions of forest site types European larch is as admixture species.

This admixture is making mainly refine function, or increasing the quality and value of produced raw wood material.

In wood production more and more attention is paid to its quality attribute, what has special importance on production for market necessity (Pazdrowski 2004.). Characteristic attribute of sapwood and heartwood can be – in dependence on wood application and species of tree – advantageous or disadvantageous traits.

Plywood industry requires sapwood, pharmaceutical and chemical industry applying heartwood and decline sapwood because of its higher permeability and minor durability (Krzysik 1978). Being familiar with the share of both types of wood in trees stems is important for wood producer as well as for wood purchaser (Pazdrowski 1992).

Quantitative proportion of heartwood to sapwood in stems of coniferous trees depends mainly on the age of the tree, the climate and soil conditions and on the level on the tree trunk from with analyzing sample is taken from the stem and on the tree crown size (Duda and Pazdrowski 1975).

In the study an effort is made to define differentiation in proportion of sapwood and heartwood on radial and axial section of the stem of the European larch trees *(Larix decidua Mill.)* representing age class IV (from 61 years old to 80 years old) and age class V (from 81 years old to 100 years old), which had grown in different forest site types, and to define the correlation between the biometric characteristic of the tree crown and the width of sapwood zone on the radius on radial section of stem of the tree.

Material and methods

Examination material contains European larch (*Larix decidua Mill.*) wood grown in the conditions of coniferous fresh mixed forest and forest mixed fresh sites, from Miradz Forest District (State Forest), which belongs to Regional Forest District in Toruń (Figure 1).

Figure 1. Localization of the Miradz Forest District (taken from: http://www.lasypanstwowe.gov.pl/mapy/index.htm)

Investigations were carried out on treestands from IV class of age (from 61 years old to 80 year old) and V class of age (from 81 to 100 years old), in which European larch occurs as admixture (not less than a group mixture type).

On each investigated area at breast heigh the diameters of trees of studied species were measured and a comparison in two centimeter class of breast height diameter was made. Then tree height was measured in proportion to the number of trees in individual diameter classes. On the basis in this way gaining height and diameter characteristic of European larch 12 model trees were chosen (3 for each area of investigation) using the Hartig's method (Grochowski 1973) and Kraft biological classification of trees. Only the first three biosocial classes were considered – which are the main trees within the stand by Kraft classification.

For each sample tree an area of tree crown projection was determined and then the tree was cut down. After this measurement of the length of living crown was made tree stem was divided in 2m sections, and from the centre of each section discs were collected, which was the background to investigate a macrostructural wood feature of wood and calculate the volume of sapwood ring and the volume of heartwood cylinder in each 2m section of a sample tree.

On collected discs the radial width of sapwood and heartwood zones was measured in four geographical directions. The arithmetic mean of the width of investigated zones of wood was used analyzing the results. The results of investigations were shown in tables and figures.

Results

Research results show the irregularity in forming heartwood in stems of European larch trees. That is why axial (along tree stem) and radial variability of the share of heart wood is observed on cross-section of tree stem.

In opinion of many authors (Jelonek and Pazdrowski 2004, Jelonek *et al.* 2006), an appearance of sapwood and heartwood in tree stems is linked with the size and assimilation and transpiration activity and productivity of living tree crown. Thus some features of sample tree crown were described (Table 2), and then the coefficient of variation was calculated from the width of sapwood zone in a tree stem (Figures 6, 7, 8 and 9)

The average share of volume of sapwood and heartwood in stems of European larch expressed in relative units is shown in Table 1.

Table 1. Average share of the volume of sapwood and heartwood in stems of European larch (*Larix decidua* Mill.)

Kraft class	IVth age class				Vth age class			
	BMśw		LMśw		BMśw		LMśw	
	heartwood	sapwood	heartwood	sapwood	heartwood	sapwood	heartwood	sapwood
I	57.7	42.3	66.2	33.8	62.0	38.0	77.8	22.2
II	48.6	51.4	72.5	27.5	64.5	35.5	75.1	24.9
III	72.2	27.8	61.0	39.0	73.9	26.1	69.8	30.2
Standard deviation	11.9		5.76		6.27		4.07	
Mean	59.5	40.5	66.6	33.4	66.8	33.2	74.3	25.7

European larch growth under the conditions of fresh coniferous mixed forest sites is characterized by the evidence of lower share of heartwood and *ipso facto* major share of sapwood in comparison to trees, which had grown under conditions of fresh forest mixed sites.

This regularity can be observed in both investigated age classes, beside this in age class V (from 81-year-old to 100- year-old) many greater differences were observed (Figure 2 a and b). On the basis of these observations it is possible to ascertain that local site type of forest significantly influences the process of heartwood production in stems of European larch. In this case fertile site type of forest ensures probably much earlier the process of heartwood type production in tree stem. The share of heartwood in the radial section was observed the highest (82.4%) in European larch grown under conditions of fresh forest mixed sites and representing V class of age (81-100-year-old), whilst the lowest share of this wood type (69.7%) was observed in tree age of class IV (61-80-year-old), which had grown on fresh coniferous mixed sites.

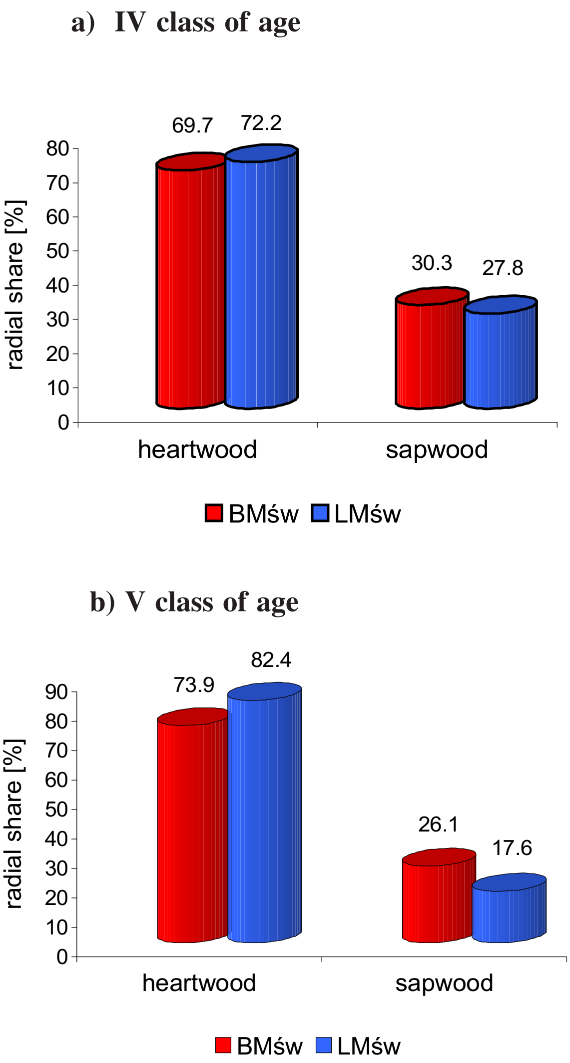

Figure 2. The mean share of sapwood and heartwood on the radius in radial cross – section of stem of European larch tree in IV and V age classes g rown under conditions of fresh coniferous mixed sites (BMśw) and fresh forest mixed sites (LMśw)

The share of sapwood and heartwood was formed inversely in relation to heartwood. The highest share of sapwood (30.3%) was ascertained in trees of IV class of age, which had grown in the conditions of fresh coniferous mixed sites, while the lowest (17.6%) was ascertained in trees of European larch representing V age class, which had grown in the conditions of fresh forest mixed sites. The share of sapwood and heartwood zones in tree stems in Kraft classes and in age classes are presented in Figure 3 a and b.

Interestingly, in both investigated classes of age the highest share of heartwood was characteristic of trees from III Kraft class and the lowest was typical of trees from II Kraft class. The share of sapwood and heartwood was in inverse proportion.

The highest share of sapwood zone (80.3%) on the radius in cross – section of tree stem was observed

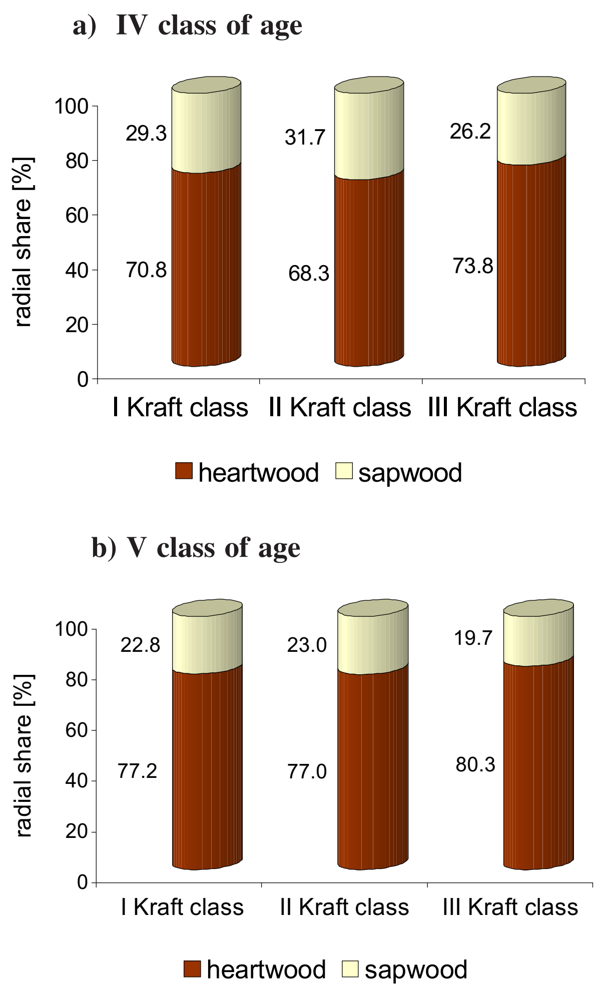

Figure 3. The mean share of sapwood and heartwood on the radius in radial cross – section of stem in European larch trees of Kraft classes representing IV and V age classes

in trees of III Kraft class, which represent V class of age, and the lowest (68.3%) in trees of II Kraft class, which represent IV class of age. Alternately the biggest radial share of sapwood (31.7%) were stated in trees of II Kraft class, which belong to IV class of age, and the smallest (19.7%) in trees of III Kraft class, which represent V class of age. Middle values were characterized in trees from I Kraft class.

This fact can be explaining that trees from III Kraft class have usually weaker build of their crown and the share of light zone in crown is minor than these of trees of I and II Kraft class. That is why its zone of sapwood is narrower than in other trees. On the contrary, trees from II Kraft class are in the stand most numerous (Jaworski 2004), and they are the main ceiling of the stand. Therefore among them the most significant variability in biometrical attribute is observed.

In turn trees from I Kraft class have the strongest advanced growth of tree crown, hence quite hegh share of sapwood zone, only a little smaller than in trees from II Kraft class (dominant).

Tree crown at each stage of advancement of stand is an attribute of vital energy, which determines its following existence in the stand. It is strongly bound with its biological development and this development in some sense is conditioned by them. Besides tree crown influences the process of wood tissue production in a tree, and many macrostructural features of wood. This article includes all above mentioned arguments, which refer to the share of sapwood in tree stems and volume with area of tree crown view, calculated correlation coefficient "r".

Table 2. Characteristic of tree crown of European larch of two age classes grown in the different types of forest sites

Kraft class	IVth age class				Vth age class			
	BMśw		LMśw		BMśw		LMśw	
	Vk [m^3]	Pk [m^2]	Vk [m^3]	Pk [m^2]	Vk [m^3]	Pk [m^2]	Vk [m^3]	Pk [m^2]
I	91.8	25.9	68.4	22	60.4	25.5	83.6	18.9
II	51.1	19.2	73.9	24.6	46.3	20.4	56.5	20.4
III	29.4	18.4	34.7	15.2	34.5	16.9	25.4	18.8
Standard deviation	31.7	4.12	21.2	4.85	12.97	4.32	29.1	0.9
Mean	57.4	21.2	59	20.6	47.1	20.9	55.2	19.4

Vk – volume of tree crown interpreted as volume of cone
Pk – area of tree crown projection interpreted as an area of circle

Gained linear correlations have worth in plus and in V age class and were much higher than in IV age class (Figures 4 and 5). In V age class the correlation between the sapwood zone width and the area of tree crown view has a similar value (0.75) and shows strong relationship of investigated traits. On the other hand, in IV age class the correlation between the sapwood zone width and the area of tree crown projection (0.36) displays low relationship of investigated traits, but between the width of the sapwood zone and an area of tree crown projection (0.53) show higher strength of associations between investigated traits.

The width of sapwood zone to a higher degree depends on the area of tree crown projection (mean value =0.64), than on the volume of tree crown in in-

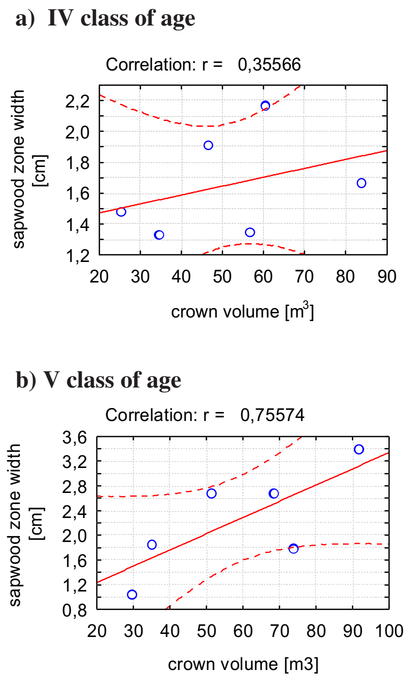

Figure 4. Linear correlation between mean value of the width of sapwood zone and volume of tree crown of European larch trees representing two class of age (95% semi-interval of confidence)

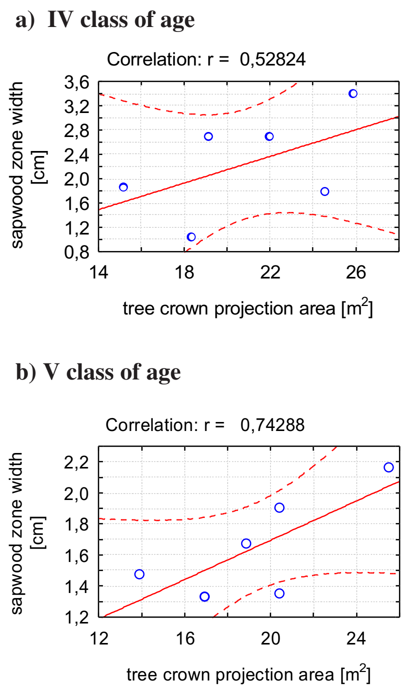

Figure 5. Linear correlation between mean value of the width of sapwood zone and area of plane projection of tree crown of European larch trees representing two class of age (95% semi-interval of confidence)

vestigated age class (mean value =0.56). Nevertheless investigated features of physiologically active tree crown have evident influence on the size of sapwood zone in tree stems.

Figures 6 and 7 show radial proportion of sapwood and heartwood location lengthwise tree stems of European larch in connection with its biosocial position held in the stand. The highest differences in the share of analyzed zones of wood lengthwise tree stem was observed in trees belonging to II Kraft class, and the smallest in trees representing III Kraft class (Figures 6 and 7).

It is worth stressing a fact that the point where the curves, representing the share of sapwood and heartwood are crossing (50% of the share from radius), is located a bit down from trees grown under the conditions of fresh coniferous forest site as compared with that originated from fresh forest sites.

It could be in some sense caused by the fact that trees from fresh coniferous forest site types had lower height than trees from fresh mixed forest sites. (Figures 6 and 7)

But in trees characterized by the same number of section (one tree from III Kraft class and V class of age) it is observed distinctly lower located point of crossing the figures representing the share of sapwood and heartwood from trees representing fresh coniferous mixed forest site.

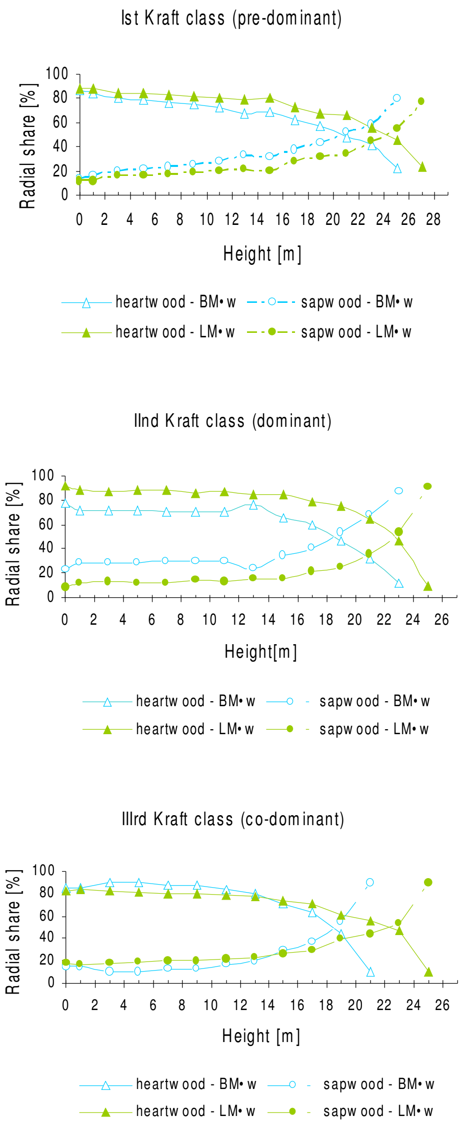

Figure 6. Percentage share of sapwood and heartwood in stems of European larch grown under conditions of coniferous mixed forest and mixed forest sites from IV class of age

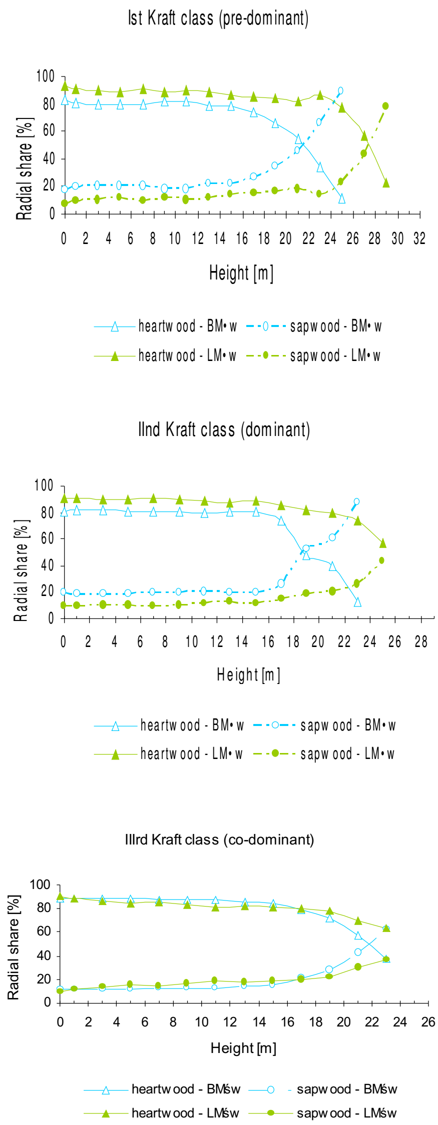

Figure 7. Percentage share of sapwood and heartwood in stems of European larch grown under conditions of coniferous mixed forest and mixed forest sites from V class of age

An interesting rarity fact can be observed in trees from II and III Kraft class which have grown under the conditions of fresh mixed forest from V class of age, where the crossing point of the figures was not observed (Figure 11). So it is quite possible that the process of the death of the cells of parenchyma is faster in the conditions of fertile habitats, which is shown by higher share of heartwood under the conditions of fresh mixed forest. Furthermore, in comparison with fresh coniferous mixed forest trees grown under the conditions of fresh mixed forest have lower area of tree crown projection which can additionally influence smaller share of sapwood.

The highest share of sapwood zone was observed at the basic part of the tree and gradually dwindled from the basic part of tree to its top. Heartwood fulfils mechanical function, that is why the highest share of sapwood occurring in the basis partial of tree stem, which is a dangerous section of the tree, the most endangered for breaking during abiotic factors, mainly the wind.

The share of sapwood zone in the first few metres increased and then gained the maximum at the top of the tree. Height share of sapwood in the higher part of a tree (closer to the top) is in interrelation with the living tree crown zone, which for its intensive transpiration needs width zone of wood which is able to transport water.

The trees have to keep balance between the zone of wood which is able to transport water and an area of active transpiration of tree crown. But this mechanism can be disturbed by the phenomenon of trees, which can change its positions in the social structure of stand, and coexist with the process of the death of branches of living tree crown (process of reduction of living tree crown).

The most labile social class is II Kraft class, because during the life of a stand it can change its biosocial position by decreasing, and exceptionally rising to another biosocial class (Jaworski 2004). This phenomenon can have a special influence on physiological activity of the crown in this much photophilous species as European larch is.

Discussion

The investigated subject except it scientific significance is also of great practical importance in wood and forest industry.

The macrostructural characteristic of wood is important in wood industry. Important elements of wood macrostructure, which have special matter in wood application are sapwood and heartwood (Jakubowski 2004). Numerous references publicize the proportions of sapwood and heartwood share on the basis of its volume in tree stems (Krzysik 1978, Pazdrowski 1992, Jakubowski 2004). Very important element, which can be useful to appreciate the quality of raw wood material, is radial share of sapwood and heartwood lengthwise tree stem (Jelonek *et al*. 2006).

Analyzing the subject of studies an effort was made to find factors influencing the irregularity of sapwood and heartwood formation in stems of trees representing two classes of age, which had grown under different conditions of forest sites types.

Jakubowski (2004) ascertains that the share of volume of heartwood in tree stem is increasing distinctly, proportionally to the age of trees. Similar dependence was observed in the present studies, where the share of volume of heartwood in trees of V class of age was higher by about 7% than in IV class of age (Table 1).

Higher share of heartwood was observed in the conditions of fresh mixed forest (LMśw), as compared with fresh mixed coniferous forest (BMśw) it can be caused by faster death of the cells of parenchyma, result from its growing old. In this way the process of heartwood production is going faster, so fertile conditions of habitat caused the faster process of heartwood production. Similar results have been obtained by Jelonek *et al* [2006] in investigating Scots pine.

Hejnowicz (2002) considered that in the process of heartwood production the time is an important factor, surely other factors have also an influence. These factors can be detailed as the following: size and efficiency of assimilation apparatus, biosocial position in the stand, genotype of the tree, geographical latitude, forest conditions type and characteristic of species features.

Stated positive correlations between the share of investigated zones of wood and the volume of tree crown as well as for tree crown view are revealed. This fact confirmed that living tree crown has an important influence on the process of heartwood production. The balance is observed between area making role in water transport and physiologically active tree crown, which assure stability of system, in which columns of water displaced in xylem under strength of transpiration (Kacperska 2002). Jelonek *et al.* (2006) stated a strong influence of the volume and area of living tree crown on the radial share of sapwood in Scots pine tree, calculated coefficient of determination.

Higher share of sapwood was observed in IV class of age as compared with V class of age. Rraw wood material from younger age class will be better for using in production of ply-wood, or for paper industry, while that from V class of age will be better for building and for chemical industry (Krzysik 1978, Jelonek *et al.* 2006).

Amongst investigated trees from the main stand (by Kraft classification) the highest share of sapwood was characteristic of trees from II Kraft classes while the smallest share was typical of trees representing III Kraft classes. These phenomena can be interpreted that trees from III Kraft classes had the smallest crown, that is why probably narrow zone of transmission, but trees from II Kraft class are the most numerous and are the main level in the stand.

Together with high frequency of trees from II Kraft class in the stand great individual differentiation occurs, which can have an influence on gaining results. The differences in the share of sapwood between I and II Kraft class were insignificant (Figure 3a and b).

Good knowledge of factors which have an influence on the process of creation of two different kinds of wood in stems of trees of the main forest species can help in the optimalisation of using raw wood material. The shape of both, sapwood and heartwood inside the stem can help in individual selection and next multiplication economical useful ecotypes of the trees.

Conclusions

1. Stated radial and axial differentiations in proportion of both types of wood in stems of European larch, which had grown under the conditions of fresh coniferous mixed forest site and fresh mixed forest site representing two age classes and different Kraft biosocial class.

2. In both investigated classes of age European larch trees grown under thr conditions of fresh mixed forest were characterized by higher share of heartwood, while the higher share of sapwood was stated under conditions of fresh coniferous mixed forest site. Fertile site of forest is given production of raw wood material with the highest share of heartwood.

3. In V age class the share of the volume of heartwood as well as on radial cross section of the tree stem was higher than in IV age class. The difference was about 7%.

4. The highest share of sapwood on radial cut (30.3%) was found in IV age class of trees grown under conditions of fresh coniferous mixed forest site, and the lowest (17.6%) in European larch tree from V class of age growth under the conditions of fresh mixed forest.

5. The highest share of heartwood in investigated age class was found in trees belonging to III Kraft class and the smallest share of heartwood was in trees from II Kraft class.

6. High value of coefficient of linear correlation “r” was stated during investigation of the coexistence between the mean width of sapwood and volume of the tree crown (0.76) and the area of tree crown view (0.74) in trees representing V age class. In trees from IV age class these coefficients were slightly lower: 0.36 and 0.53 in due correlations. Worth to additional remarks is a fact, that living tree crown has influence on the share of sapwood and takes part in the process of heartwood production in stems of European larch. This subject is very complicated and further complex investigations are necessary.

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РАДИАЛЬНАЯ И ОСЕВАЯ ИЗМЕНЧИВОСТЬ УЧАСТИЯ ЗАБОЛОНИ И ЯДРА В СТВОЛЕ ЕВРОПЕЙСКОЙ ЛИСТВЕННИЦЫ *(LARIX DECIDUA MILL.)*

М. Наврот, В. Паздровски и М. Шимански

Резюме

В данной работе предпринята попытка определить радиальную и осевую изменчивость участия заболони и ядра у стволов европейской лиственницы, произрастающей в различных природных условиях.

Для лиственницы выросшей на плодородных почвах, т.е. в смешанном-свежем лесу, характерно преобладание ядра и меньше участие заболони. Обратная картина наблюдалась у деревьев произрастающих в условиях смешанного-свежего бора.

У деревьев IV класса возраста (от 61 до 80 лет) наблюдалось меньше участие ядра и больше развитие заболони, чем у лиственниц принадлежащих к V классу возраста (от 81 до 100 лет). Эта зависимость была замечена при изучении обоих типов лесов.

Замечено неравномерное радиальное и осевое участие обоих видов древесины в стволах лиственницы в исследуемых типах смешанных лесов и возрастных классах, а также на фоне биосоциального положения деревьев.

На образование заболони и ядра в стволе, а также на скорость этого процесса скорее всего влияют размер и эффективность транспирации крон деревьев, биосоциальное положение и природные условия произрастания.

Отчетливое влияние физиологически активной кроны на зону заболонной древесины в стволе дерева подтверждено благодаря вычислению коэффициента корреляции “r” соотношения между шириной зоны заболони и ее объемом, а также площадью проекции кроны.

Ключевые слова: лиственница европейская, заболонь, ядро, бор смешанный-свежий, лес смешанный-свежий